If you are using a printed copy of this procedure, and not the on-screen version, then you <u>MUST</u> make sure the dates at the bottom of the printed copy and the on-screen version match.
The on-screen version of the Collider-Accelerator Department Procedure is the Official Version.
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C-A OPERATIONS PROCEDURES MANUAL

18.8.1 Procedure for ECX Fast and Slow Tuner

Text Pages 2 through 8

Hand Processed Changes

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Approved: ___________***Signature on File***_________________ ______
Collider-Accelerator Department Chairman Date

C. Pai

18.8.1 Procedure for ECX Fast and Slow Tuner

1. Purpose:

The purpose of this procedure is to provide instructions to the operator of the fast and slow tuner of the ECX Superconducting RF cavity. This tuner is an electro-mechanical system. It consists of two separate functioning tuners, fast tuner by Piezo Drive and slow tuner by Stepping Motor. It is installed inside the ECX cryostat. It will be operated during ECX Cold Emission Test to tune the frequency of RF cavity.

2. Responsibility:

2.1 The tuner is a subsystem of the ECX 5 cell superconducting RF cavity. The operator of the tuner should follow the directions of the coordinator of ECX cold emission test to operate this tuner to change the frequency of RF cavity as required.

2.2 The operator should be familiar with the tuner mechanism and specification before operation. The tuner mechanism and specification are provided as an attached document in this procedure.

3. Prerequisites

Training

- The operator shall have the following valid training as minimum
- TQ-ELECSAF1, Electrical safety I
- HP-OSH-151B-W, Lock Out/Tag Out- Authorized

4. Precautions

4.1 The tuner operates by physically stretching the length of the 5 cell cavity to change RF frequency. The operation of the tuner shall be as smooth as possible and do not apply unnecessary stress on the RF cavity.

4.2 The tuner is installed on the cold body of RF cavity. During operation, motor and piezo drive will generate heat. The generated heat will be dissipated by conduction. The operator shall monitor the temperature of the tuner system, so there is no build up heat from the tuner to affect the performance of the superconducting RF cavity. The maximum allowable temperature of tuner system is room temperature. But if temperature rise in the RF cavity is higher than desired, the tuner should be stopped and kept cooler than this point, so it won’t affect the performance of the RF cavity.

4.3 In order to operate in vacuum environment and cryogenic temperature, Dicronite Coating was used as dry lubricant in all sliding and rotating surfaces of the tuner drive system. To prevent quick depletion of the dry lubricant, the operation of the tuner shall be limited to only as needed.

5. **Procedure**

5.1 Coarse tune:

a. When RF cavity system is cold and ready, set the stepping motor running parameters as described in the paragraph 1.6 of the attached Tuner Mechanism and Specification.

b. Zero the motor step count to indicate the initial position.

> **Note:**
> The initial position is the tuner installed position and is no load

c. When tuner is needed to tune the RF cavity, run the motor by sending the exact number of pulses to actuate the tuner. The tuning coefficient is 0.21 Hz per each quarter step.

d. For each continuous motor run, limit the total quarter step number of pulses to no more than 185,200 pulses or 40.5 KHz. After each run let the motor rest about 10 minutes for cool down. The running time for 185,200 quarter steps is about 46.3 seconds. The temperature rise rate of the motor is about 5^{o}K per minute run. The maximum operating temperature of the motor is 300^{o}C. This motor relies on dry lubrication. For better performance give the motor enough time to cool and get a more uniform temperature distribution.

e. When the RF cavity reaches its frequency, stop the motor and keep the motor in this step count. The tuner system has self locking capability and will keep the RF in this frequency.

f. Repeat procedure steps c to e when tuning is needed.

g. The full range of the coarse tune is 0 to 740,800 quarter steps or 0 to 162 KHz. Two limit switches were installed to set the upper and lower bound of the tuner motion.

h. Return the tuner to its initial position before cavity system warm up.

5.2 Fine Tune:

a. When cavity system is cold and ready, zero the piezo driver voltage to indicate the initial position.

Note:
The initial position is the free state of Piezo drive with no load

b. The piezo drive fine tuner is independent of coarse tune. When fine tune is needed, drive the piezo drive by applying the needed voltage as shown in the piezo chart in paragraph 1.8 to change the RF cavity frequency. The piezo uses a set of capacitors to maintain the tuning force voltage. The voltage has to be applied constantly to retain the frequency.

c. The full range of the fine tune is 0 to 1000 Volt. or 0 to 2080 Hz.

d. When micro phonic compensation is needed a wave generator with the needed frequency and voltage can be applied to drive the piezo drive.

e. Return the piezo drive to its initial position before the cavity system is warmed up.

6. Documentation

None

7. References

7.1 Drawing #010601259, ECX RF TUNER ASSEMBLY.

7.2 Phytron Extreme Environment Stepping Motor Spec and Parameters,
Type: VSS57.200.2.5-space-KTC-K1
Manufacturer: Phytron Inc.
Tel. 802-872-1600 x1110
www.phytron.com

7.3 Harmonic Drive Spec and Parameters.
Type: Harmonic drive is HDC-014-100-2A-SP2413
Manufacturer: Harmonic Drive LLC
Tel: 978 573-3420
www.harmonicdrive.net

7.4 Piezo Drive Spec and Parameters:
Type: PSt 1000/25/300 VS 35
Manufacturer: Piezomechanik GmbH
Phone: +49 (0)89-431-5583
www.piezomechanik.com

8. Attachment:

Tuner Mechanism and specification

1. Tuner Specification

1.1 Tuner mechanism:

The ECX tuner mechanism is a double lever linkage which combines two stages of mechanical leverage to gain force advantage. The tuner pulls the RF cavity to change its length. When RF cavity length changes the RF frequency changes too. This tuner is self locking. It can stay in any position within its operational range. (DWG: 010601259)

1.2 Tuner leverage ratio:
a. First stage: 2.28
b. Second Stage: 7.5
c. Total leverage: 14.5

1.3 Tuning range:
a. Fundamental RF mode: 703.75 MHz.
b. Stiffness of RF cavity: 39,000 lb/in
c. Tuning coefficient: 100 Hz/μm.
d. Tuning range: 0 to 162 KHz (one side)

Note:
This range is limited by the strength of RF cavity which has to meet the ASME Pressure vessel code VIII requirement.

e. Max. Mechanical stretching of RF cavity: 1.63 mm

Note:
At 1.63 mm stretching, the maximum stress in the cavity is 4000 psi, less than 2/3 of yield strength of niobium.

f. Max. Stroke of tuner drive: 23.5 mm (.926")

1.4 Method of RF cavity tuning

a. Coarse tune:

A stepping motor/ACME thread drive system is used in the second stage of the tuner to drive the RF cavity to change its full range frequency. The coarse tuner uses the full mechanical advantage, R=14.5, to tune the RF cavity and is controlled by counting the pulses of stepping motor to move the tuner mechanism.

b. Fine tune:

A piezo drive system is installed in the first stage to provide fine tune and microphonic compensation. The tuning range of the piezo drive is 20 µm or 2000 Hz. The piezo drive is controlled by applying electric voltage. Fine tune is independent from coarse tune. It can be operated in any coarse tune position to do fine tune of the cavity frequency.

1.5 Coarse tuner specification:

a. Mechanical advantage: 14.5

b. Drive system:
Stepping motor: 200 step/rev
Harmonic reducer: 100:1
ACME screw size: ½”-10 (10 threads per inch)

c. Maximum Driving force at full tune:
Pulling Force at RF cavity: 2503 lb @ 1.63 mm stretching.
Thrust Force at ACME power nut: 172 lb. @ 23.6 mm stroke

d. Motion relation:
Leads per motor step:
Motion in ACME drive: 5.0×10^{-6}in.
Stretch in RF cavity: 8.758×10^{-3} µm.

e. Tuning coefficient: 0.87Hz/motor step
(If motor runs in ¼ steps, the tuning coefficient is .21 Hz/quarter step)

1.6 Speed of coarse tuning and motor parameters:

a. Motor speed: 300 rpm. (3 rpm @ ACME screw)

b. Motor acceleration: 37.5 rpm/sec

c. Voltage: 40 V

d. Current: 1.7 AM

e. Step size: 1/4 (quarter step)

f. Running current limit: 2.0 AM.

g. Total required step in full tuning:
For full step: 185,200 step for 162 KHz tuning.

For quarter step: 740,800 step for 162 KHz tuning.

h. Time needed for full tuning range: 3 min. 5.2 sec.

i. Operating environment: The whole tuner system operates in vacuum and cryogenic environment. The motor temperature raises about 5 ^{o}K in each minute of operation. It cools down about 1.2 ^{o}K in every 10 min. It is recommended to run the rotor no longer than a minute in each operation then let it cool down at least 10 minutes before restart. The maximum allowable temperature of tuner system is room temperature. But if temperature rise in the RF cavity is higher than desired, the tuner should be stopped and kept cooler than this point, so it won't affect the performance of the RF cavity.

1.7 Fine tuner specification:

a. Mechanical advantage: 2.28

b. Drive type: Piezo drive.

c. Maximum Driving force at full tune: (20 µm or 2000 Hz @ RF cavity)
Pulling Force at RF cavity: 30 lb @ 20 µm stretching.
Thrust Force at Piezo drive: 14 lb. at 45.6 µm stroke

1.8 Tuning control of Piezo drive (Fast tune):

a. Piezo driver: The piezo is driven by voltage from 0 to 1000 Volt.

b. The following table shows the relationship of applied voltage and tuning frequency:

Note:
This relationship is derived by strain gage reading in a room temperature test. In the cold temperature this number may reduced by factor of 5 to 10. This table uses reduction factor of 5 for reference

Voltag e	Stain Gage reading (mu)	Applied force lbs	Frequency Change, Hz
0	418	0.0	0.0
100	419	1.6	104.2
200	421	4.8	312.6
300	422	6.4	416.8
400	424	9.6	625.2
500	426	12.8	833.6
600	428	16.0	1042.1
700	430	19.2	1250.5
800	433	24.0	1563.1
900	435	27.2	1771.5
1000	438	32.0	2084.1

1.9 Tuner monitoring devices:

a. Linear Variable Differential Transformer LVDT

A calibrated LVDT (SM-3) is installed to provide direct readout of the stretching of the RF cavity. The frequency change of cavity can be calculated by tuning coefficient, 100 Hz/ μm.

ΔHz=Tuning coefficient X stretching

Where Tuning coefficient is 100Hz/μm

Stretching is in μm.

b. Two strain gages, one each in the flex link, will provide the micro strain in the flex link. The tuning force being applied to the RF cavity can be calculated by this micro strain.

Force (lb) = gage number x A x micro strain x Young's modulus

= 8 x micro strain

Where gage number is 2 gages.

A=.25 in^2 (flex link cross section area).

Micro strain is the read out from strain gage.

Young's modulus is 16 for titanium (the 10^6 factor is canceled with micro strain).

c. Tuner frame temperature monitoring:

Three thermal diodes were installed in the tuner frame for temperature monitoring.

d. Stepping motor temperature monitoring:

The motor has a built in thermal couple for temperature monitoring.